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PROCEEDINGS

OF THE

AMERICAN ACADEMY

OF

ARTS AND SCIENCES.

VOL. XXV.

PAPERS READ BEFORE THE ACADEMY.

I.

CONTRIBUTIONS FROM THE PHYSICAL LABORATORY OF THE MASSACHUSETTS INSTITUTE OF TECHNOLOGY.

XXXIV. — TELEPHONIC SPECIFIC INDUCTIVE CAPACITY.

By F. H. Safford and G. U. G. Holman.

Presented by W. W. Jacques, December 11, 1889.

In a paper on the Construction of Telephone Circuits, read before this Academy on the 15th of June, 1887, by the Electrician of the American Bell Telephone Company, Dr. Jacques, it was pointed out "that the readiness with which telephonic conversation may be carried on over any circuit, whether made up of cables or pole lines, or both, depends, —

"1. On the total electrical resistance of the circuit joining together the two stations.

"2. On the total electrostatic capacity of this circuit."

And the general rule was laid down: —

"No matter what may be the distance between two points, good business conversation may be carried on between them, provided they be connected by a pole line or cable, or both, the product of whose total resistance by its total capacity is less than 2,000, if transmitters of the Blake type be used, and less than 4,500, if transmitters of the Hunnings type be used."

It is evident, therefore, that in the construction of a telephone line it is desirable to reduce both the *resistance* and the *capacity* to a minimum.

In a pole line, since the wire is suspended high above the earth, the capacity is always small, and the resistance is the factor that we must try to keep down.

In cable lines, however, where the conductor is necessarily brought near to other conductors, or a metal shield, or the earth, the capacity becomes quite an important factor to be respected.

In lines made up, as is most generally the case, of a comparatively short section of cable and a larger section of iron pole wire, the capacity of the cable becomes pre-eminently the factor to be respected; for, since the limit of conversation is here determined by the product of the capacity of the cable and the resistance of the whole line, a small percentage of saving in the capacity of the cable gives an enormous gain in the readiness with which conversation may be carried on over the line.

It becomes of vital importance, therefore, to choose an insulating material for telephone cables of low specific inductive capacity.

We have accordingly measured the electrostatic capacity of a considerable number of substances used for insulating wires in cables, and, since the specific inductive capacity for the same insulator is very different for telephone currents from what it is for telegraph currents, because the charge and discharge take place so much more frequently, we have adopted a method and apparatus in which currents of telephonic frequency are used.

This apparatus is a Gordon induction balance, (see Gordon's Electricity and Magnetism, p. 110,) in which the substances were charged and discharged by currents from an induction coil, and the balance was observed with a telephone instead of an electrometer.

With this apparatus, we measured the specific inductive capacity of a considerable number of insulating materials, and each when subjected to various rates of charge.

We found that the capacity varied very materially with the rate of charge, some substances increasing and others decreasing, but no general rule was evolved.

We found that measurements of the capacities of telephone cables made by the ordinary galvanometric measurements gave no indications of the comparative merits of these cables for telephonic work.

Finally, we made an accurate series of measurements of the specific inductive capacity of the following substances, when submitted to actual telephone currents. The values might perhaps be called the "telephonic specific inductive capacity," leaving the expression "telegraphic specific inductive capacity" to indicate values measured in the old-fashioned way.

TABLE OF SPECIFIC INDUCTIVE CAPACITIES, MEASURED BY TELEPHONE CURRENTS.

Petroleum (Brooks Cable)	1.6
Solid paraffine	2.0
Cotton saturated with paraffine in vacuum (Faraday Cable)	2.0
Cotton boiled in paraffine (Patterson Cable)	2.6
India-rubber	3.7
Artificial gutta-percha (Gwynn)	3.9
Gutta-percha	4.2
Glass	4.6
Water	6.3

An inspection of this table shows that, so far as capacity is concerned, petroleum is the best substance to be used, and doubtless this would be the case were it possible to keep it free from water; but water, we see from the table, has a specific inductive capacity of 6.3, so that its presence in the petroleum raises the capacity from the lowest to the highest in the list.

This observation is borne out by actual experience with "Brooks" cables in telephony. When new, and the petroleum dry, it works excellently; but as water finds its way in, the cable rapidly loses its efficiency for telephonic work.

This action of the water is quite different from its action as a *conductor* to produce leakage, for the loss of electricity due to leakage in a Brooks cable that has lost its efficiency from the presence of moisture is entirely insufficient to account for the deterioration.

Next to petroleum, solid paraffine is seen to be the best substance to use; but on account of mechanical difficulties it has never been found practicable to coat wires directly with solid paraffine.

If the wires are wound with cotton and then boiled in paraffine, as they are in making "Patterson" cables, the specific inductive capacity is raised to 2.6, an increase of 30%, which we have seen is a very great detriment.

If, however, the wires are wound with cotton, and the air and moisture removed by the aid of heat and a vacuum, and they are then boiled in paraffine, from which the air and moisture have also been removed by heat and vacuum, the specific inductive capacity again falls to 2.0, which is the same as that of solid paraffine. This is the process used in preparing the "Faraday" cable.

It is possible that the inferiority of the Patterson cable as compared with the Faraday is due largely to the moisture retained in the cotton, which we have seen has a capacity of 6.3.

Leaving the paraffine cables, rubber is the next best, then gutta-percha, and poorest of all is glass; but all of these substances have so high a specific inductive capacity as to entirely unfit them for telephonic work.

ROGERS LABORATORY OF PHYSICS,
November, 1889.